CLAIMS

What is claimed is:

1. A method for detecting ice on a surface comprising:

acquiring a reflectance spectrum of light reflected off of a surface to be tested;

calculating a midpoint wavelength of a transition in the reflectance spectrum;

comparing the midpoint wavelength to a decision threshold wavelength; and

identifying ice on the surface if the midpoint wavelength is greater than the decision threshold wavelength.

2. The method of claim 1, wherein the step of acquiring the reflectance spectrum comprises detecting reflected light off of the surface with a near-infrared camera.

3. The method of claim 2, wherein the step of acquiring the reflectance spectrum comprises detecting reflectance levels at three wavelength bands.

4. The method of claim 3, wherein the three wavelength bands are centered at approximately 1.3 microns, 1.4 microns, and 1.5 microns.

5. The method of claim 3, wherein the three wavelength bands have center wavelengths and bandwidths of 1.30 microns +/- 0.04 microns, 1.4 microns +/- 0.04 microns, and 1.5 microns +/- 0.04 microns, respectively.

6. The method of claim 3, wherein the three wavelengths have center wavelengths and bandwidths of 1.30 microns + 0.04 microns / -0.20 microns, 1.40 microns +/- 0.05 microns, and 1.5 microns + 0.20 microns / -0.05 microns, respectively.

7. The method of claim 3, wherein the three wavelengths have center wavelengths and bandwidths of 1.30 microns +/- 0.02 microns, 1.40 microns +/- 0.02 microns, and 1.50 microns +/- 0.02 microns, respectively.

8. The method of claim 3, wherein the three wavelengths have center wavelengths and bandwidths of 1.30 microns +/- 0.02 microns, 1.38 microns +/- 0.03 microns, and 1.45 microns + 0.1 microns / -0.02 microns, respectively.

9. The method of claim 1, wherein the step of comparing the midpoint wavelength to the decision threshold wavelength comprises comparing the midpoint wavelength to a decision threshold wavelength of 1.4 micrometers.

10. The method of claim 1, wherein the step of calculating the midpoint wavelength of the transition comprises applying a decision function to reflectance levels of the reflectance spectrum to obtain a dimensionless number corresponding to the midpoint wavelength.

11. The method of claim 10, wherein the decision function is:

$$F = \frac{(R_a - R_b) * (R_b + R_c)}{(R_b - R_c) * (R_a + R_b)}$$

wherein *Ra, Rb,* and *Rc* are three reflectance levels measured at three wavelengths *a*, *b*, and *c,* and *F* represents an absolute value.

12. The method of claim 10, wherein the step of comparing the midpoint wavelength to the decision threshold wavelength comprises comparing output of the decision function to a predetermined range.

13. The method of claim 12, wherein the pre-determined range is approximately 0.25-2.5 for bandwidths of 5 to 20 nanometers and center wavelengths of 1.30 microns, 1.40 microns, and 1.50 microns, respectively.

14. The method of claim 12, wherein the pre-determined range is approximately 0.025 – 0.10 for bandwidths of 5 to 20 nanometers and center wavelengths of 1.300 microns, 1.357 microns, and 1.450 microns, respectively.

15. The method of claim 12, further comprising indicating the presence of ice on the surface when the midpoint wavelength falls within the predetermined range.

16. The method of claim 1, wherein the step of indicating the presence of ice on the surface comprises generating an audio or visual indication of the presence of ice on the surface.

17. A method for detecting liquid water on a surface comprising:

acquiring a reflectance spectrum of light reflected off of a surface to be tested;

calculating a midpoint wavelength of a transition in the reflectance spectrum;

comparing the midpoint wavelength to a decision threshold wavelength; and

identifying liquid water on the surface if the midpoint wavelength is less than the decision threshold wavelength.

18. The method of claim 17, wherein the step of acquiring the reflectance spectrum comprises detecting light reflected off of the surface with a near-infrared camera.

19. The method of claim 18, wherein the step of acquiring the reflectance spectrum comprises detecting reflectance levels in three wavelength bands.

20. The method of claim 19, wherein the three wavelength bands are centered at approximately 1.3 microns, 1.4 microns, and 1.5 microns.

21. The method of claim 19, wherein the three wavelength bands have center wavelengths and bandwidths of 1.30 microns +/- 0.04 microns, 1.4 microns +/- 0.04 microns, and 1.5 microns +/- 0.04 microns, respectively.

22. The method of claim 19, wherein the three wavelength bands have center wavelengths and bandwidths of 1.30 microns + 0.04 microns / -0.20 microns, 1.40 microns +/- 0.05 microns, and 1.5 microns + 0.20 microns / -0.05 microns, respectively.

23. The method of claim 19, wherein the three wavelength bands have center wavelengths and bandwidths of 1.30 microns +/- 0.02 microns, 1.40 microns +/- 0.02 microns, and 1.50 microns +/- 0.02 microns, respectively.

24. The method of claim 19, wherein the three wavelength bands have center wavelengths and bandwidths of 1.30 microns +/- 0.02 microns, 1.38 microns +/- 0.03 microns, and 1.45 microns + 0.1 microns / -0.02 microns, respectively.

25. The method of claim 17, wherein the step of comparing the midpoint wavelength to the decision threshold wavelength comprises comparing the midpoint wavelength to a decision threshold wavelength of 1.4 micrometers.

26. The method of claim 17, wherein the step of calculating the midpoint wavelength of the transition comprises applying a decision function to reflectance levels of the reflectance spectrum to obtain a dimensionless number corresponding to the midpoint wavelength.

27. The method of claim 26, wherein the decision function is:

$$F = \frac{(R_a - R_b) * (R_b + R_c)}{(R_b - R_c) * (R_a + R_b)}$$

wherein *Ra, Rb,* and *Rc* are three reflectance levels measured at three wavelengths *a*, *b*, and *c*, and *F* represents an absolute value.

28. The method of claim 26, wherein the step of comparing the midpoint wavelength to the decision function wavelength comprises comparing output of the decision function to a predetermined range.

29. The method of claim 28, wherein the pre-determined range is at least 10 for bandwidths of 5 to 20 nanometers and wavelengths of 1.30 microns, 1.40 microns, and 1.50 microns, respectively.

30. The method of claim 28, wherein the pre-determined range is 1.0 - 10 for bandwidths of 5 to 20 nanometers and wavelengths of 1.300 microns, 1.357 microns, and 1.450 microns, respectively.

31. The method of claim 28, further comprising indicating the presence of liquid water on the surface when the midpoint wavelength falls within the predetermined range.

32. The method of claim 17, wherein the step of indicating the presence of liquid water on the surface comprises generating an audio or visual indication of the presence of liquid water on the surface.

33. A method for detecting whether ice or liquid water is present on a surface comprising:

measuring three reflectance levels of light reflected off of a surface in three wavelength bands;

calculating a midpoint wavelength of a transition using the three reflectance levels;

indicating the presence of ice on the surface if output of the decision function falls within a first pre-determined range; and

indicating the presence of liquid water on the surface if output of the decision function falls within a second pre-determined range.

34. The method of claim 33, wherein the step of measuring the reflectance levels comprises detecting reflected light off of the surface with a near-infrared camera.

35. The method of claim 33, wherein the three wavelength bands are centered at approximately 1.3 microns, 1.4 microns, and 1.5 microns.

36. The method of claim 33, wherein the three wavelength bands have center wavelengths and bandwidths of 1.30 microns +/- 0.04 microns, 1.4 microns +/- 0.04 microns, and 1.5 microns +/- 0.04 microns, respectively.

37. The method of claim 33, wherein the three wavelength bands have center wavelengths and bandwidths of 1.30 microns + 0.04 microns / -0.20 microns, 1.40 microns +/- 0.05 microns, and 1.5 microns + 0.20 microns / -0.05 microns, respectively.

38. The method of claim 33, wherein the three wavelength bands have center wavelengths and bandwidths of 1.30 microns +/- 0.02 microns, 1.40 microns +/- 0.02 microns, and 1.50 microns +/- 0.02 microns, respectively.

39. The method of claim 33, wherein the three wavelength bands have center wavelengths and bandwidths of 1.30 microns +/- 0.02 microns, 1.38 microns +/- 0.03 microns, and 1.45 microns + 0.1 microns / -0.02 microns, respectively.

40. The method of claim 33, further comprising measuring reflectance levels in four or more wavelength bands.

41. The method of claim 33, wherein the step of calculating the midpoint wavelength of the transition comprises applying a decision function to the three reflectance levels to obtain a dimensionless number corresponding to the midpoint wavelength.

42. The method of claim 41, wherein the decision function is:

$$F = \frac{(R_a - R_b) * (R_b + R_c)}{(R_b - R_c) * (R_a + R_b)}$$

wherein *Ra, Rb,* and *Rc* are three reflectance levels measured at three wavelengths *a*, *b*, and *c*, and *F* represents an absolute value.

43. The method of claim 33, wherein the first pre-determined range is approximately 0.25-2.5 for bandwidths of 5 to 20 nanometers and center wavelengths of 1.30 microns, 1.40 microns, and 1.50 microns, respectively.

44. The method of claim 33, wherein the first pre-determined range is approximately 0.025 – 0.10 for bandwidths of 5 to 20 nanometers and center wavelengths of 1.300 microns, 1.357 microns, and 1.450 microns, respectively.

45. The method of claim 33, wherein the second pre-determined range is at least 10 for bandwidths of 5 to 20 nanometers and center wavelengths of 1.30 microns, 1.40 microns, and 1.50 microns, respectively.

46. The method of claim 33, wherein the second pre-determined range is approximately 1.0 - 10 for bandwidths of 5 to 20 nanometers and center wavelengths of 1.300 microns, 1.357 microns, and 1.450 microns, respectively.

47. The method of claim 33, further comprising indicating the absence of ice and liquid water on the surface when the output of the decision function falls between the first and second predetermined ranges.

48. An apparatus for detecting the presence of ice or liquid water on a surface comprising:

a light source for illuminating a surface to be tested;

a detector for detecting at least three reflectance levels *Ra, Rb,* and *Rc* at three wavelengths *a*, *b*, and *c*; and

a signal processor having a decision function for determining the presence of ice or water on the surface based upon the at least three reflectance levels *Ra, Rb,* and *Rc*.

49. The apparatus of claim 48, wherein the light source comprises one of an incandescent light, a laser, an LED, or sunlight.

50. The apparatus of claim 48, wherein the detector comprises one of a near-infrared detector, an infrared camera, an InGaAs focal-plane array, or a PbS vidicon.

51. The apparatus of claim 48, further comprising a spectrally-selective element for measuring the at least three reflectance levels.

52. The apparatus of claim 48, wherein the signal processor indicates the presence of ice on the surface when the output of the decision function falls within a first predetermined range.

53. The apparatus of claim 52, wherein the signal processor indicates the presence of liquid water on the surface when the output of the decision function falls within a second predetermined range.

54. The apparatus of claim 53, wherein the signal processor indicates the absence of ice and water on the surface when the output of the decision function falls between the first and second predetermined ranges.

55. The apparatus of claim 48, wherein the decision function is:

$$F = \frac{(R_b - R_c) * (R_a + R_b)}{(R_b + R_c) * (R_a - R_b)}$$

where F represents an absolute value.

56. The apparatus of claim 48, further comprising an ambient light detector connected to the signal processor for measuring ambient light levels.